No. 6 How To Test and Replace Resistors and Volume Controls

RADIO SERVICING METHODS

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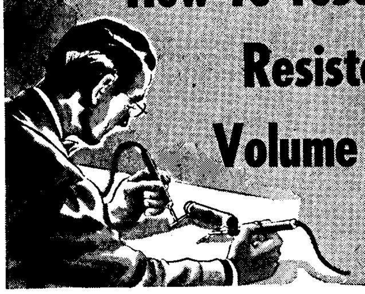


How To Test and Replace Resistors and Volume Controls

YOU are now ready to learn how to test and replace radio parts. From this RSM Booklet, you will learn how to deal with fixed and variable resistors; later Booklets will take up the testing and replacement of condensers, coils, and other radio parts. (Remember—these are the *mechanical* procedures of servicing, which are undertaken only after tests have isolated a part that may be defective. Your Lessons in Radio Fundamentals and later RSM Booklets will teach you the methods of isolating defective parts.)

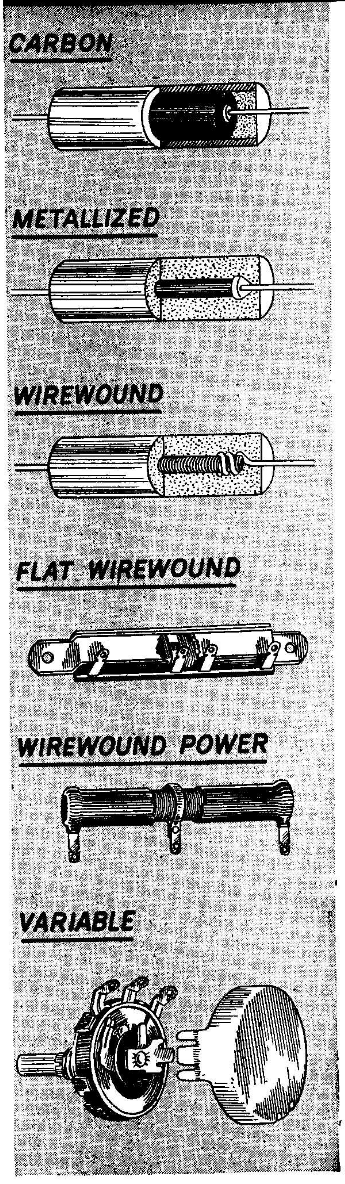
At this moment, you may not be ready for all the information this Booklet gives you. We suggest you read it through now without worrying about any sections you may not understand completely. Retain mentally the facts that are useful to you now, and review the Booklet a few times when you've gotten farther along in your Course. You'll need all this information later on, when you're engaged in actual servicing.

RESISTOR DEFECTS

First, let's learn something about the defects found in each type of resistor. In the following, notice how the manner in which each is made determines what may be the trouble. Hence, it pays to know how radio parts are constructed—this knowledge helps you see what may go wrong.

Carbon Resistors. These, the most common fixed resistors, are subject to several possible defects. An open

TYPICAL RESISTORS



Carbon resistors are made of carbon granules mixed with a binder (bakelite or a ceramic), cut in a rod-like shape, and baked. After leads are attached, bakelite is molded over the assembly.

A metallized resistor is made by coating a glass rod with resistive material. Usually bakelite is molded over the metallized rod. Such a resistor is very stable in its value.

A wire-wound resistor is made by winding a resistance wire, such as nichrome, on a porcelain or bakelite tube or rod. The entire device is then coated with a vitreous enamel, a cement, or a special varnish.

A flat wire-wound resistor is made by winding resistance wire on a bakelite or fiber form. The entire unit is then molded in bakelite, or wrapped in insulating paper, and cased in a metal container.

A wire-wound power resistor is a large wire-wound resistor fitted with taps at various points along its length. Some types are equipped with variable taps, others have only fixed taps.

A variable resistor consists of a resistance element with a slider contact. The rheostat has only two outside connections; one to one end of the resistance element, the other to the slider contact. Another type, known as a potentiometer, has a connection at each end of the resistance element and a third connection to the slider.

circuit is common, as carbon resistors are easily broken, and they will open if excessive current flows through them; this current burns away the carbon particles in a section of the resistor. Also, they decrease materially in resistance when a current somewhat above their rated current flows through them. This last peculiarity may upset the circuit conditions in the stage in which they are used. The resistor may return to its normal value when it becomes cool, but eventually this decrease in value may become permanent.

Carbon resistors rarely short-circuit internally. Many are so molded that the resistance element is completely surrounded by the binder material, which acts as an insulator. If you are careful to bend the leads so they do not touch other leads or other parts, there is little likelihood that a carbon resistor will cause a short circuit in a set.

Metallized Resistors. Like carbon resistors, these also can open internally, for excess current will burn away the resistive material and leave no path through which current can flow. However, because of the strength of the glass rod, these resistors are not easily broken. They seldom change in value.

Wire-Wound Resistors. Excess current flowing through a wire-wound resistor will cause the resistance wire to melt at some point and thus open the circuit. Wire-wound resistors seldom break or change materially in value. However, the method of fastening the connecting leads may permit a poor contact to develop at the clamp.

► Flat wire-wound resistors seldom break or change materially in value, but they do open (the resistance wire burns apart) when excess current flows through them, and poor contacts sometimes develop inside their cases between the leads and the resistance element. Occasionally, the resistance element will short through the insulating paper to the metal container. (One type of flat wire-wound resistor is known as a Candohm, from "canned ohm," because the resistance is placed in a metal container.)

► Wire-wound power resistors have the same troubles

as ordinary wire-wound resistors. However, individual sections usually are affected, rather than the entire unit.

Summary of Troubles. You can see that fixed resistors may open internally, change in resistance value, have loose terminals, or short-circuit to other parts or leads. Now, let's see how to check resistors for these faults.

BURNED-OUT OR OPEN RESISTORS

When a resistor has been severely overloaded, it will sometimes be blackened and blistered, or even burned almost in half. Obviously, you need not check such a resistor—just reach for a replacement.

However, the external appearance of the resistor does not usually indicate anything. An open resistor can look just like a good one. You must use the ohmmeter section of your multimeter to detect the difference.

► If you are interested only in finding out whether or not a resistor is open, you need not bother to read the ohmmeter scale accurately. If the battery within the ohmmeter can force a current to flow through the resistor and thus cause a meter reading, the resistor is *not* open. If you get no reading (the meter pointer does not move), the resistor *is* open. To make such readings, use the highest ohmmeter range of your test instrument. If this range will indicate higher values than the largest-valued resistor in the set, then you can check *any* resistor and get a reading on the ohmmeter scale if the resistor has continuity (is not open). However, any resistor having a higher value than the highest ohmmeter range will not permit a noticeable pointer movement—don't assume such high-value resistors are open unless you have other reasons to suspect them.

► After setting the multimeter controls to the highest ohmmeter range, how does one check a resistor for an open? If the resistor is disconnected from everything, you need only touch its terminals with the ohmmeter test probes, as in Fig. *1*, and watch the meter for a reading.

Sometimes the same simple procedure can be followed when checking a resistor that is connected into a circuit. However, there are *two* important precautions to observe when you use an ohmmeter to make tests within a radio:

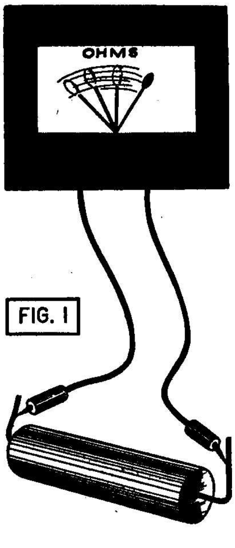


FIG. 1

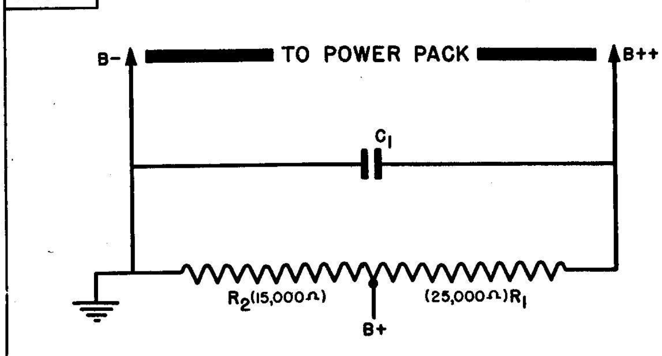
1. *ALWAYS be sure the receiver is turned OFF. If the receiver operates from batteries, COMPLETELY DISCONNECT them. Otherwise your ohmmeter may be ruined by excess current.*

2. *Disconnect one end of the resistor being checked, when shunt paths may give false readings.*

Shunt Paths. Shunt paths occur whenever parts in parallel allow more than one path over which current can flow. This will cause false readings. For example, suppose you wish to check voltage divider resistors R_1 and R_2 in Fig. *2*. You would put one ohmmeter test probe on the end of R_1 that goes to B++, and the other on the end of R_2 that goes to the chassis. (The chassis is indicated by the ground symbol.) You might expect the ohmmeter to read 40,000 ohms, the combined values of R_1 and R_2 (25,000 ohms plus 15,000 equals 40,000 ohms).

However, even a meter reading near the proper value is not definite proof that these resistors are in good

FIG. 2



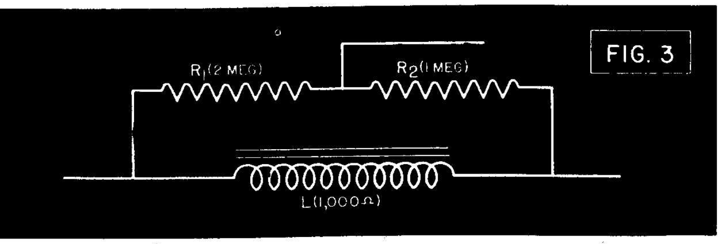


FIG. 3

condition. Perhaps one of them is actually open and condenser C_1 is leaky.* Notice that condenser C_1 connects directly across R_1 and R_2. If the condenser is leaky, there will be a direct current path through the condenser as well as through the resistors.

Fig. *3* shows a voltage divider connected across a coil (a fairly common circuit in power-supply filter sections). Here, the coil creates a shunt path for either resistor. If you put your ohmmeter test probes across the terminals of resistor R_2, you would actually have the circuit shown in Fig. *4;* there would be a path through R_1 and L, which are effectively in parallel with R_2. In the same way, if you connected your ohmmeter test probes across R_1, the ohmmeter current would flow through R_2 and L.

Therefore, unless you know definitely that there is no possibility of shunt paths, unsolder one end of a resistor from the circuit before you check it. You can then apply the test probes between the two terminals of the resistor and be sure that you are checking only that part.

► Naturally, the fact that you are looking for continuity does not prevent you from reading the resistance value on the ohmmeter scale if you want to. At times this is very desirable, because it helps you to identify the resistor being checked.

CHANGES IN RESISTANCE VALUES

Let us now suppose that the operation of the radio

*Condenser failures will be taken up in another RSM Booklet. For now, just remember that condensers sometimes "leak"; that is, their insulation breaks down, and they act like resistors.

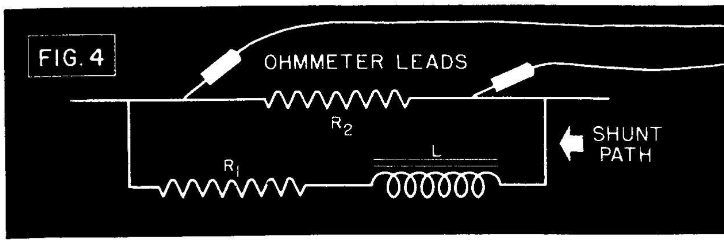


FIG. 4

has led you to suspect a change in resistance value. To check this, you will have to read the ohmmeter, rather than just notice whether or not its pointer deflects.

Of course, before you can say definitely that a change has taken place, you must know the original value of the resistor. You can find this from the service information or schematic diagram of the radio, or you may know enough about the circuit and the use of the resistor to be able to judge what its value should be. (Sometimes you will find that a resistor is marked with its original value, either by a stamping, or by the use of colors. We shall describe these methods of marking later.)

Once you know what the value ought to be, measure the actual resistance of the resistor with your ohmmeter. The ohmmeter scale is always more accurate near the center of the scale, so, if possible, choose a range that will give a reading nearest the center of the meter scale. However, except for accuracy, it makes little difference which range is used, as long as the deflection can be read.

Again, be careful about shunt paths. Disconnect the resistor if there is any doubt about there being a shunting path.

LOOSE TERMINALS

In practically all cases, loose terminals on a resistor will cause the receiver to be noisy—a characteristic frying, crackling sound, along with the desired sounds, comes from the speaker. If you suspect a certain resistor of being the source of noise, you can check it by leaving the receiver turned ON and wiggling the connections on that resistor. It is best to use an insulated test probe or

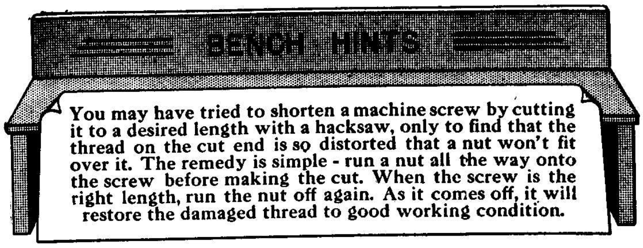
wooden stick for this. (Sometimes a serviceman grasps terminals with a pair of pliers to wiggle them. There is always danger of getting a severe shock when one does this, so we don't recommend it.) If wiggling the lead causes the particular noise to come from the speaker (or makes it louder), then the resistor is probably faulty. However, remember that moving a lead may move other parts also. There may be a loose connection at the other end of that particular wire. Be careful to introduce the least possible disturbance, so that you can be more certain you have found the defect.

► You can also use an ohmmeter to check the resistor for loose terminals. With the set turned *OFF*, clip the ohmmeter test probes to the terminals of the suspected resistor, then jar or wiggle the terminals. (It is desirable to disconnect the resistor from the other parts when making this test, so that the reading will be accurate.) If there is a loose terminal, the ohmmeter reading will vary as the connecting leads are moved.

SHORT CIRCUITS

In practically all cases involving resistors, short circuits occur because the resistor or its leads are allowed to touch the chassis or other parts. Watch for such conditions and you'll seldom have trouble.

Of course, as we said, the flat wire-wound resistor known as the Candohm will sometimes short between the resistance element and the metal container. To check for this condition, disconnect all terminals of the resistance element from the circuit, and use an ohmmeter to check between the resistor terminals and the container. Be careful when you make this check, because sometimes one of the terminals on a Candohm is supposed to connect to the metal container; this is how a connection to the set chassis is made in many receivers. Where this is true, naturally that particular terminal will show zero resistance to the container. Furthermore, there will be a resistance reading between other terminals and the container, the exact value depending upon the amount of resistance between the grounded terminal and the terminal to which the measurements



Our long experience in radio servicing has taught us many practical ways of doing mechanical jobs that we would like to pass on to you. However, very often these practical hints do not fit into the subject matter of these RSM Booklets. We have therefore adopted the idea of presenting this information in the form of bench hints, like the one shown above. You will find hints of this sort in future Booklets wherever there is sufficient space for us to put them in. Watch for them—the practical information they give you will prove helpful in your servicing work.

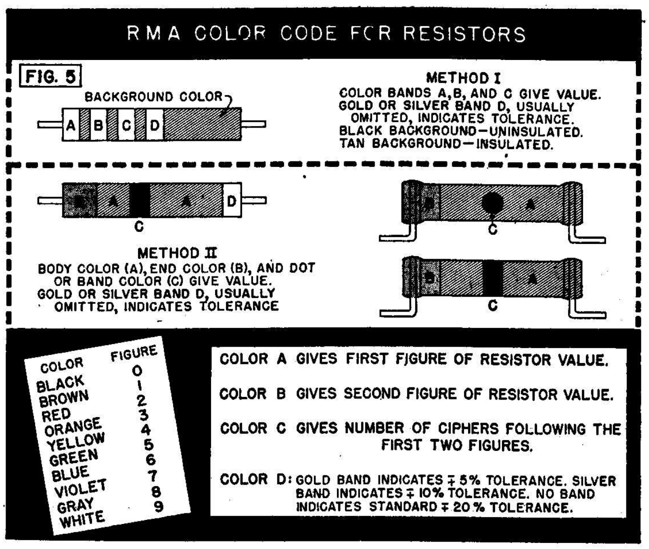
are being made. However, if any value is lower than its rated amount, then there may be a short to the container. You will have to disconnect the resistor to make further tests.

CHOOSING THE PROPER REPLACEMENT

Once you've found the defective part, you should replace it. Naturally, the more closely you can duplicate the original part value, the more nearly the receiver will perform as it did originally. Therefore, consult the manufacturer's service information to find the right resistance value. The physical size of the resistor is no guide at all to resistance value—a resistor one-half inch long may have a resistance of 100 ohms or of 10 megohms.

Any replacement resistor you buy or have in your shop will usually be labeled to show its resistance value. Carbon and metallized resistors usually are color-coded; sometimes the resistance value is also stamped right on the resistors. Wire-wound resistors usually have paper or metal tags attached to them that give the resistance values.

Color Code. There are several methods of painting the colors on the resistors, but the standard systems are



EXAMPLES

COLOR A	COLOR B	COLOR C	OHMS
Brown	Black	Black	10
Yellow	Violet	Black	47
Brown	Black	Brown	100
Orange	Green	Brown	350
Brown	Black	Red	1000
Red	Orange	Red	2300
Brown	Black	Orange	10,000
Blue	Gray	Orange	68,000
Brown	Black	Yellow	100,000
White	Brown	Yellow	910,000
Brown	Black	Green	1,000,000

shown in Fig. 5. This is known as the R.M.A. (Radio Manufacturers Association) Color Code.

As a serviceman, you will find the color code helpful in identifying resistors within the receiver, and in identifying the values of those in your stock. However, if you keep a color-code chart handy, you don't need to memorize it. In time, you will automatically learn the colors on the more common resistors. You can always check replacement resistors with your ohmmeter; most servicemen do this anyway, even after having identified the resistor by the code.

Don't expect *all* colored resistors to follow the standard code—those in many early receivers were marked by private manufacturer's codes.

Common Resistor Values. As you progress in your Course and study actual receiver diagrams, you will find that certain values of resistance are frequently used. In particular, 25,000-, 50,000-, 100,000-, 250,000-, 500,000-ohm, 1-megohm, and 2-megohm resistors are very common.

However, many manufacturers do not use these exact values. Instead, they use odd values such as 22,000, 47,000, 91,000, 270,000, and 470,000 ohms. These values are used simply because it is easier to see the color codes on them under factory lighting conditions. If you ever have to replace one of these odd-value resistors, you can generally use the nearest standard size with entire satisfaction. Usually a value 20% higher or 20% lower than the original value can be used unless otherwise specified on the wiring diagram. This means, for example, that any value between 80,000 ohms and 120,000 ohms may be replaced by a 100,000-ohm resistor.

On the other hand, if the diagram or the color coding of the resistors indicates that a resistor having a 5% or a 10% tolerance was used originally, it is usually advisable to stay within this tolerance.

It may seem strange that such large variations are permissible, but you will find wide tolerances of this type in most mass-production electronic devices because many radio circuits are self-adjusting. The manufacturer knows that, on the average, the differences will cancel and the over-all results will be satisfactory.

Wattage Ratings. When you have determined the proper resistance value to use, you next need to determine the wattage rating of the replacement. The replacement must have a rating at least as high as that of the original and preferably higher. If the resistor is too low in its wattage rating, it will overheat, which will cause it either to change its value or eventually open.

These ratings are not ordinarily given on wiring diagrams, but the size of the original resistance is a rather good guide to its wattage rating. Fig. *6* shows a num-

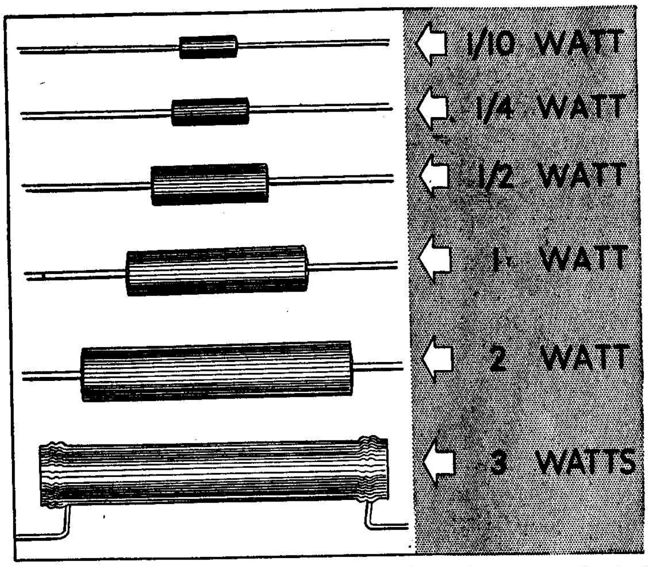


FIG. 6. The wattage rating of a resistor depends upon its physical size. This illustration shows the actual size of typical resistors of various wattage ratings.

ber of ordinary resistors in actual size with their wattage ratings marked beside them. As you will notice, the larger the resistor is physically, the greater its wattage rating. (The wattage rating depends on the *physical size,* not on the resistance.) You see, in general, the wattage rating depends on how well the resistor can dissipate heat; the larger its surface area, the greater the amount of heat a resistor can transfer to the surrounding air.

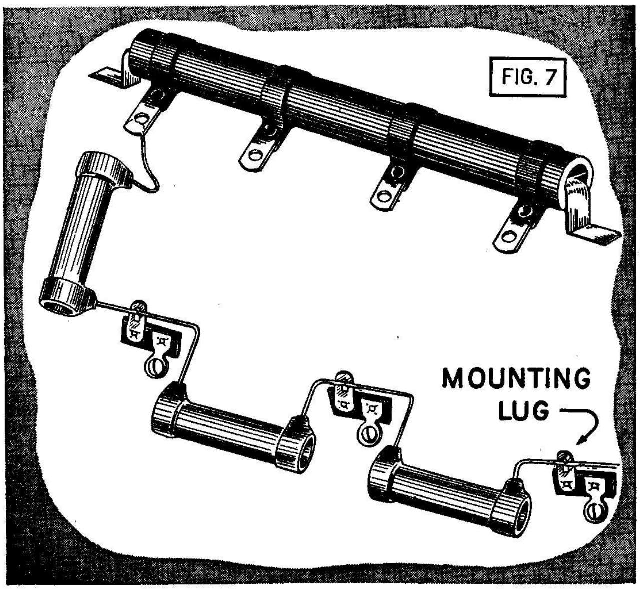
The wattage ratings of voltage-dividing resistors are rarely given. However, occasionally you will find a receiver using individual 4- or 5-watt carbon resistors as voltage dividers. These resistors will become defective eventually, and it is wise to replace them with 10-watt wire-wound resistors to prevent further trouble. Remember, you can always use a higher wattage rating —this just gives a greater safety factor.

Therefore, *you can always use a resistor that is physically larger than the original resistor, as long as the resistance rating is either the same or within the tolerance limits.*

► When only a single section of a multisection voltage divider opens up, many servicemen just connect a replacement resistor across the terminals of the defective section. Don't do this unless you destroy the defective section *permanently* by cutting it with a file or knife, so that it will never come back to life and upset the circuit voltages. Better yet, use a replacement voltage divider intended for that particular receiver; this will replace all the original voltage divider, and you won't have to worry about wattage values.

Occasionally, a replacement voltage divider is not available. If you know the values of each section, you may be able to use individual 10-watt resistors to replace the original, as shown in Fig. 7. However, these require mounting lugs (insulated supports to hold the resistors away from the chassis) for which there is not always room.

You may also use a general purpose voltage divider



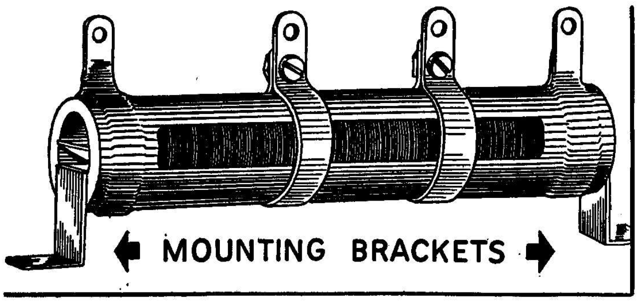


FIG. 8. Typical power resistor with variable taps. The mounting brackets shown are made of spring material so that the resistor can be removed or replaced with little difficulty.

having adjustable sliding contacts. Obtain one that has a total resistance value as near as possible to the total of the original divider. Install it as shown in Fig. *8*, at some convenient point, or in place of the defective divider. Then, move each slider until voltmeter readings show that you have the proper voltages. To avoid shocks, remember to turn off the receiver when moving these sliders, then turn on the receiver again to measure the voltage.

Facts To Remember. When a resistor burns out, you may be sure that excess current has flowed through it or that its wattage rating was too low to carry the normal circuit current over a long period of time. The wattage rating of any replacement must always be equal to or *greater* than that of the original resistance, and the replacement resistor value must be within the normal tolerance limits for the particular circuit.

Before soldering in the replacement resistor, find out whether excess current can flow through the replacement. The trouble may have been caused by some other part defect, such as a breakdown in a condenser. In another RSM Booklet, we shall show in detail how to check for such troubles. As a general rule: BEFORE REPLACING ANY RESISTORS, CHECK THE CIRCUIT TO SEE IF THE FAILURE WAS CAUSED BY A CIRCUIT DEFECT.

How To Test And Replace Volume And Tone Controls

The replacement of volume and tone controls is a mechanical service job which you will do many, many times. It's simple, but there are certain points to keep in mind.

How Controls Are Made. Volume controls and many tone controls are physically alike—the only difference is in their use. (We are speaking now of tone controls that can be continuously varied—not the kind that can be changed only in steps. These latter use switches.) Hence, whatever we say about one applies equally to the other. Both may be either *rheostats* or *potentiometers.* A rheostat (Fig. *9A*) is a variable resistor having two terminals. One terminal connects to one end of the resistance unit, the other connects to a slider that is moved along the unit as the shaft is rotated.

A potentiometer (Fig. *9B*) has three terminals. Terminals are connected to each end of the resistance element instead of to just one end, as in the rheostat. (Of course, you can use a potentiometer as a rheostat just by ignoring one of the end terminals.)

Another less common control has a tap (Fig. *9C*). This extra tap is fastened to the resistance unit and is connected to a condenser or an electrical network to provide automatic-bass compensation—a circuit action that will be discussed in another lesson.

Some volume controls are double units rotated from a single shaft. Also, some receivers use concentric shafts (a shaft within a shaft) to control in-

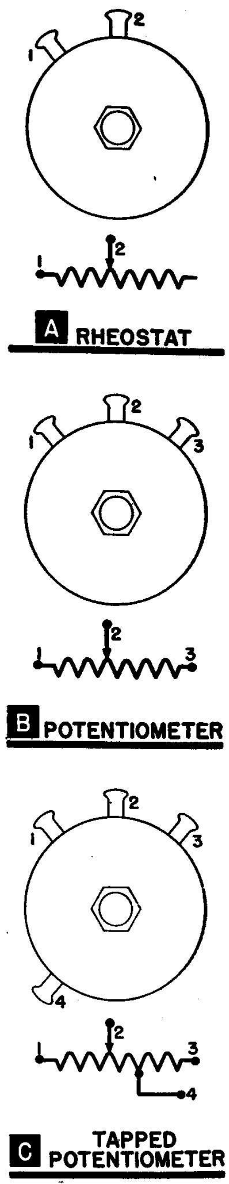


FIG. 9

dividual units mounted together. These and other special units require exact duplicate replacement parts.

Volume and tone controls frequently have an On-Off switch or a phono-radio switch mounted on the control. This switch is so mounted that turning the control shaft first operates the switch, then varies the resistance of the control.

Volume and Tone Control Defects. Since a volume or tone control contains a movable part that must slide over the resistance element, the element will be worn out eventually by friction. Poor contacts also develop between the rotating arm and the connecting terminal in some types. Then, too, circuit breakdowns sometimes occur that cause excess current to flow through the resistance element and destroy it.

► A good control must have three characteristics:

1. It must be noiseless in action.

2. It must control the volume or the tone.

3. It must be smooth in action (give a steady increase or decrease without sudden changes).

Tests seldom need to be made on a variable control to prove that it is bad. Usually a worn control will cause a very noticeable amount of noise. If the receiver is noisy when the control knob is pulled, pushed, or turned, or becomes more noisy as the control is rotated, then the control is defective and should be condemned at once.

If the volume control has no control whatever over the volume, probably there is a break or an open near one terminal. (On the other hand, if a tone control has no effect on the receiver tone, it is more common to find that some associated part is defective.) Sudden jumps and erratic control of the volume or tone indicate an internal defect or a worn element. Usually there will be some noise when this last condition is noted.

Obtaining Replacement Controls. To obtain a replacement volume or tone control, give your supplier the make and model number of the receiver. If the receiver is a standard make, an *exact duplicate* replacement or a *general purpose* replacement will be available for it and will be listed in the volume control guide books.

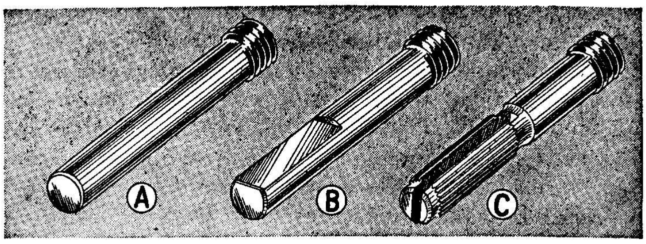


FIG. 10. Typical volume control shafts: A, round; B, half-round; C, slotted.

Sometimes, particularly if the receiver is of unknown make, you must give the resistance value and the circuit connections of the control. (The Lessons in Radio Fundamentals describe the many ways of connecting volume and tone controls, together with the details of resistance values needed.)

Naturally, if you're not using an *exact duplicate* control, the shaft on the replacement control should be similar to that of the original. Fig. *10* shows several shaft types. If the original has a switch, order a similar switch with the replacement.

Of course, if you carry volume controls in your stock of parts, you will undoubtedly use them wherever possible. A volume control guide book published by the manufacturer of the brand of control you carry will show you which control to use for the particular receiver.

Now let's run through the steps for installing a control. First, we'll consider *exact duplicate* controls, then *general replacement* types.

INSTALLING EXACT DUPLICATE CONTROLS

Never disconnect any defective radio part until the replacement has been obtained. If you unsolder leads to check the part, put them back in place until you have the replacement.

► As the first step in replacing a defective control, draw a sketch showing all the connections to the old control. An *exact duplicate* control will be exactly like the old one and will need to have the same connections. If you

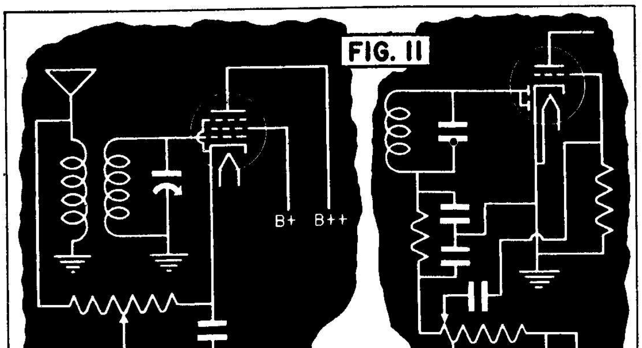
make this sketch before going further, you won't have any trouble in making the replacement.

Fig. *11* shows two typical volume control circuits in schematic form. Underneath them are sketches such as you might draw before disconnecting the leads to the old control. (The round object with two lugs at the center of the back of the control represents the On-Off switch.) To make the sketches, work from the back view of the control, as this is the normal position from which you will replace the leads.

After sketching the lead connection arrangement, unsolder the leads from the volume control terminal lugs, one at a time. Naturally, the receiver should NOT be plugged in the power line.

Occasionally you will find two or more leads, fastened to a single lug, that have been inserted through holes in the lug and twisted so that they are hard to get off. In such cases, cut the leads as close to the control as possible, or cut off the lug and pull it out where you have more

FIG. II



room to work. Twist together these leads (that go to the *same* lug) after they are unsoldered.

When the leads are all removed from the old control, take off the nut holding the control to the chassis and remove the control. You can generally use slip-joint auto pliers to loosen the nut, but the special socket wrench that fits volume-control nuts is better.

► Next, put the shaft of the new control through the chassis hole. If a lock washer is furnished, place it over the shaft and then thread on the nut holding the control to the chassis. Do not draw the nut up tightly, however; allow the control to be loose until the leads are soldered so you can turn it to the easiest position for soldering. After soldering all the leads, recheck against your sketch to be sure you have them properly placed. Then, tighten the volume control holding nut as much as possible. If the nut is not tightened fully, the customer may turn the whole control when he turns the knob and so break leads off the control. There may be (on the front or shaft side of the control) a projecting metal or bakelite tab that fits into a hole in the chassis wall when the control is properly located. If so, be sure it is in its hole before tightening the holding nut.

INSTALLING A GENERAL REPLACEMENT CONTROL

A *general replacement* volume control or tone control is a unit that is electrically similar to the original control, but may be somewhat different in physical size and form. (If it is larger than the original, be sure you have room to mount it before trying to install it.) In addition, since the replacement control is designed to fit a number of different receivers, it will have an extra-long control shaft, often much longer than is necessary.

Most general purpose controls do not come with switches on them, but a switch can be added simply by removing a back-plate of the control and installing a new plate that has the switch mounted on it.

► After obtaining the recommended general replacement control and a switch, if needed, your next step is to draw a picture of the arrangement of the leads. Then,

remove all leads from the defective control and take it out.

Use your ohmmeter to check between the terminal lugs and the shaft of the old control. Many controls have an internal connection between the shaft and a terminal that should be grounded, thus making an automatic ground. *An exact duplicate control will have this feature, but a general replacement will not.* Therefore, if you find continuity between any terminal and the shaft of the old control, you will have to provide a ground connection between the proper terminal on the new control and the set chassis. Add this connection to your sketch.

► The next step is to cut the shaft of the replacement control to the right length. Measure the length of the old shaft with a ruler or caliper from the point where the body of the control touches the chassis wall. Mark off the shaft of the new control to the same length with a pencil or crayon. Then put the shaft (*not* the control itself—see Fig. *12*) in a vise and cut it off at the marked length with a hacksaw. Smooth the cut edge of the shaft with a file.

► Next, add the On-Off switch to the control if one is

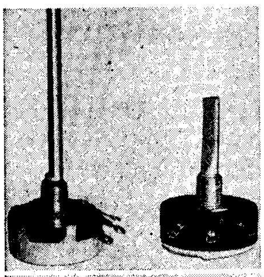
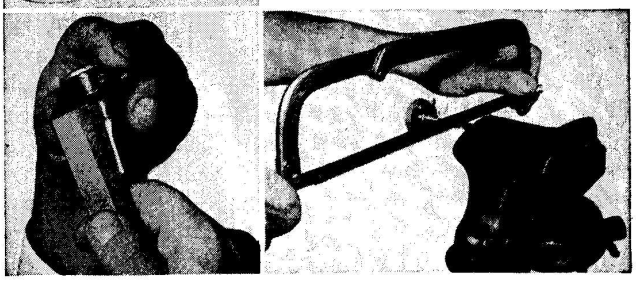


FIG. 12. The shaft of a general replacement control is extra long. To cut it to the right length, first measure the exact length of the original control shaft with a ruler. Transfer this measurement to the shaft of the replacement control, then cut off the replacement control shaft to the marked length with a hacksaw.



used. Remove the plain back-plate of the control by lifting a clamping lug (or two) that holds it down. You will then find that the new back-plate with the On-Off switch will slip into place easily. Rotate the shaft of the control to approximately the mid-position. Then put the switch on, hold it in place with your hand, and turn the volume control shaft all the way counter-clockwise. This should make the switch snap off. It should snap on again when you turn the control to the right (clockwise). This shows that the switch is in the proper position, so you can attach the back permanently. (Since controls differ in their clamp arrangements, the switch you use must be intended for the brand of control you are installing.)

Finally, slip the shaft through the chassis hole and start the holding nut. Connect the leads according to your sketch, then tighten the holding nut.

Summary. The replacement of a defective volume or tone control may be broken down into the following simple steps:

1. Obtain the replacement.
2. Draw a picture sketch of the connections.
3. Remove the connecting leads and the defective control.
4. For a general replacement control, check for a grounded terminal on the original; cut the shaft to the right length; add a switch if one is used.
5. Install the new control with its nut loose.
6. Solder the connecting leads to the proper terminals on the replacement control.
7. Tighten the control holding nut.